Advances in vessel and aircraft technologies

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14. ABSTRACT
This report provides an overview of robotics technologies in Japan, including comparatively recent history. Topics include major laboratories and commercial firms that are leading research and development of robotics in Japan, including humanoid robots.

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Introduction

This report will focus on robotics technologies in Japan, including recent history. The author has studied this field for the past several years. Some of the information within the report goes back to a study done in 2005, in support of a visit to Japan by Dr. Garry Shields, Director of the Advanced Visualization Office, NAVSEA, who showed interest in Japanese robotics technologies.

Japan is the world's leader in robots for industrial use. New technologies and new applications continue to emerge. In an attempt to cultivate future markets for robots, the Ministry of Economy, Trade and Industry (METI) of the Japanese government has urged the robotics community to strive towards the realization a Robot Society. Substantial research is now focused on the service (non-manufacturing) area, which will surely have an impact on future automation technology worldwide.

Japanese Robotics Overview

Japan is regarded as the Number 1 robotics country, by its own assessment and those of others. Japan's government recently reported that other countries, such as the USA, are making inroads into Japan's leadership position, but it is still easily leading the world. It produces roughly two-thirds of all robots worldwide, and nearly one-third of all robots are in Japan. Japan will for the foreseeable future dominate the

worldwide business in industrial robots (specifically in manufacturing environments). Industrial robots were created in the US in the early 1960s, but since then Japan has been continuously improving its technology for industrially viable products. The secrets of its success lie in:

(1) Japan is equipped with all of the technology required for successful robotics. Although Japan may not be the best in the world in each of the individual areas, such as mechanics, electronics, motion control, computer software, or sensor technology, all readily available.
(2) Japan is strong in industries that support implementation of robots in practical use, such as automobile manufacturing, machinery, electronic industry, and others.
(3) In the 1970s and 1980s, robotization took place to overcome labor shortages.

One of the best Japanese contributions to robotics has been the electrification revolution in robot anatomy. Japan is overall the strongest country for electric drives, power electronics, and precision motion-control technology. Japan has introduced new technologies for electric servo-drives, together with microprocessor-based control into robot controls. As a result, nowadays hydraulically or pneumatically driven robots are seldom in use. With this new generation, robots have been introduced into automotive, electronic, and machinery industries.

Their application encompasses welding, machining, materials handling, painting, dispensing, assembling, etc.

Electric drives have paved a way to diversifying robotics architectures into, for example, vertically articulated SCARA robots and parallel-link types. In early 1990, Yasukawa Electric developed a new servomotor that was about one-half the size and one-third the weight of previous ones. Taking advantage of these new lightweight, powerful servomotors, a new robot type ("linkless" structure) was made possible. It is now a standard mechanical configuration for industrial robots. In the 1990s, information-technology-related business began to pick up. New robots for clean-room environments, some in vacuum, for micro-semiconductor fabrication emerged. As the demand for flat display panels for PCs, cellular phones, and game machines expanded, new needs for handling larger glass plates were perceived. Japan has developed such application-specific robots, which have grown to be a major market. Japan will doubtless continue to be the leader in industrial robot business and related technology.

Japanese industrial robotics are contributing to the world by improving existing product lines, opening new application areas (Fig. 1), and producing peripheral devices. The Japan Robot Association (JARA) is proposing standardization of interfacing protocols for communication (Fig. 2) and net plug-in actuators, to name two.

Fig. 1. Vacuum robot.

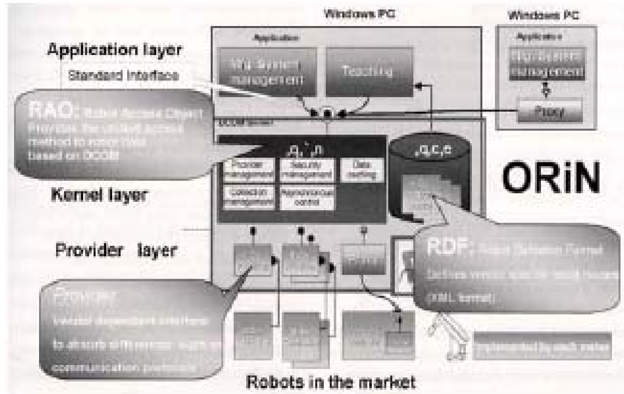

Fig. 2. Open robot interface network.

Japanese robotics manufacturers are not, however, satisfied with their current positions. For instance, it is claimed that arc welding is one of the best applications of industrial robots. Robotic welders replace human labor in dirty, dangerous, and demanding environments. In reality, the number of arc-welding robots is only one-tenth that of arc-welding machines. Most arc welders are still operated by humans. Other statistics show that 85% of robotics installations are found in large enterprises with more than 300 workers, and that the remaining 15% are in smaller ones. Considering the fact that only 20% of the total Japanese labor pool works in large enterprises, it is clear that the robot density per human worker in smaller enterprises is less than one-twentieth of that in bigger enterprises. The implication of these statistics is that current industrial robotics technology is best-suited to mass, larger-scale production. It may be less well-suited to the smaller-lot, versatile production. The future trend is toward versatile products fulfilling the wants of individuals, and so industrial robots will need to be flexible, user-friendly, and perhaps lower cost. With these

thoughts in mind, Japanese robotics manufacturers are aiming at more-sophisticated, intelligent robots for applications in modern world. This increased attention should have another impact on automated machines and systems in general.

One must keep an eye on Japanese efforts in industrial robotics. The field is changing rapidly and the speed of change will accelerate with time.

The Direction of Japanese Robotics

It is widely perceived among the worldwide robotics community that the existing industrial-sector market is comparatively stagnant and that few new business opportunities in non-manufacturing area are evident. Japan is no exception. Japanese mass media are enthusiastically talking about human-like robots such as Honda's Asimo and Sony's Aibo, but nobody can predict how these fun-robots will ever contribute to better lives for human beings, yet alone constitute a profitable future business.

For many years, concerns had grown over the future of the robotics industry. Some critics believed that researchers have achieved much in development of innovative prototypes, but that industry had been unconvinced of the merits of the innovations and had stuck to older, established technologies. Years ago, one sensed that perhaps a new direction was needed. It was with this background in mind that in 2000

METI prompted JARA to study a new strategy for the Japanese robotics industry. The outcome of this survey was published as a report "Technology Strategy for Creating a "Robot Society" in the 21st Century." This report constitutes the national guideline of Japanese robotics for the future.

The report predicted a market size $30 billion in 2010 and $80 billion in 2025 (exchange rates can influence these numbers considerably). Primary fields of advance were envisioned to be:

(1) Manufacturing (human/machine-coordinated systems, eco-factories, network-compatible factories)

(2) Biotechnology (automated analysis equipment, automatic synthesis systems, bio-factories)

(3) Public domain (disaster prevention, disaster rescue, disaster prediction, etc.)

(4) Medical/welfare (disease prevention, diagnosis, cure, rehabilitation, labor saving in medical facilities, intelligent systems, medical education, etc.)

(5) Human life (education, virtual training at home, entertainment- based rehabilitation, communication aid, life support, etc.).

These figures were, however, revised downward in the New Industry Promotion Strategy adopted in 2004: $18B for 2010 and $62B for 2025.

The current industrial robotics market is still characterized as mass-produced, standard robots for use by industrial professionals. The future market of the robotics industry will likely be different in terms of:

(1) Personal-use orientation (versatile needs, various kinds of products, production in small quantities)
(2) Non-sophisticated users, including the general public.

The report concluded that Japan must create a new robotics strategy that can meet individual, versatile requirements of the new markets to emerge and must define a new approach: Robotic Technology (RT). Robotics will expand from what it is now to encompass intelligent, automated system technologies of wider scope. In the future, robotics-solutions business will play an essential role in RT. Robotics manufacturers should supply not only robotics products, but also robotics technology to solution providers so that they can easily tailor systems to individual requirements. The report predicted that this new kind of business will become the mainstream of the future market. In compliance with the new trend, future robotics technology must be so-called "open" oriented. The "open" concept encompasses open architecture of technology, standardization of robotics system components, and open technology disclosure. To achieve the envisioned future, collaboration among industry/government/academia was viewed to be a requirement.

Leading Business Enterprises and Academia in Robotics

Robots:

Industrial robots: Fanuc, Yasukawa Electric, Kawasaki Heavy Industries, Kobe Steel, DAIHEN, Toyoda Machine Works, Nachi-Fujikoshi, Mitsubishi Electric, Yamaha Motor

Non-manufacturing robots; Honda Motor, Toyota Motor, Fuji Heavy Industries, Toshiba, Mitsubishi Heavy Industries, Sony, Fujitsu, NEC, Matsushita Electric Works, Hitachi, Ishikawajima-Harima Heavy Industries, Kawada Industries, Bandai, Palbox, Omron, Sohgo Security Services, Secom, Tmsuk, Japan Logic Machine, ZMP

Sensors:

Image sensors:

CCD: Sony, Matsushita Electric, Sharp, FUJIFILM Microdevices, Hamamatsu Photonics

CMOS: Mitsubishi Electric, Toshiba, Olympus, Hitachi, Fujitsu

Ultrasonic sensors: Nippon Ceramic, Murata Manufacturing

Force sensors: Nitta, BL Autotech

Gyro sensors: Murata Manufacturing, NEC Tokin, Matsushita Electronic Components, Sumitomo Precision Products, Tokimec

Drive Components:

Linear motors: Yasukawa Electric, Sodick Plastics, Hitachi Metals, Yokogawa Electric

Servo motors: Yasukawa Electric, Mitsubishi Electric, Sanyo Denki, Matsushita Electric, Fanuc, Tamagawa Seiki, Omron

Linear guides and X-Y tables: THK, NSK Precision, Nippon Thompson, Union Tool, Chuo Precision

Speed reducers: TS Corp, Harmonic Drive Systems, Sumitomo Heavy Industries

Intelligent Control:

2-legged walking technology: Honda Motor, Sony, Kawada Industries, Fujitsu Automation, General Robotix

Facial expression control: AGI, Kokoro

Voice-response technology; Asahi Kasei voice interface project, NEC System Technologies

Artificial intelligence: InterRobot, CAI, A.G.I.

Advanced and basic technology: Univ. of Tokyo, Waseda Univ., Nagoya Univ., Tokyo Institute of Technology, Tsukuba Univ., Tohoku Univ., Kobe Univ.,

Osaka Univ., Kyoto Univ., Ritsumeikan Univ., Hiroshima Univ., Kyushu Univ., Kyushu Institute of Technology, National Institute of Advanced Industrial Science and Technology (AIST), RIKEN

Service Robots

The business of robotics for the non-manufacturing sector (generally called service robots) continues to be developed. In some specific applications, robots are already playing an indispensable role. For instance, in nuclear power-generation plants, remote manipulators are used to replace human workers in radioactive environments. The importance of robots cannot be overlooked. However, this remains a small market for the robotics industry.

To address the labor-shortage concerns of the 1970s and 1980s, many prototypes were developed for the public sector. Similar efforts are still going on in various non-industrial applications. For maritime applications, research on remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) is in progress. As an example, an AUV for inspection of submarine cables for telecommunications is shown in Fig. 3.

The AUV “Aqua Explorer” was developed to investigate sea-bottom conditions before a cable is laid and laying/buying conditions after it is in place. Aqua Explorer was the first small commercial AUV for submarine

cable inspection in the world. The conceptual and basic design of the vehicle and the control software of the AE series were developed by KDDI R&I Laboratories. The vehicle was built by Mitsui Engineering and Shipbuilding Co.

Aqua Explorer has endurance of longer than 8 hours for practical cable-tracking missions. Its length is 3 m and its weight is 300 kg. It allows easy handling, including launch and recovery work.

Apart from these commercial applications, a breakthrough might be possible through research in gigantic projects such as of space development, ocean exploitation, military hardware, and others that could justify the needed huge investments in new science and technology. Again, the field of robotics may need a drastically new strategy. Such a strategy is the objective of MITIs guideline.

Fig. 3. AUV “Aqua Explorer” for submarine cable inspection (KDDI & MES).

Humanoid Robots

Since the advent of Honda's ASIMO and Sony's AIBO, robot fever broke out in the general public of Japan. It remains active today. The annual service robot show ROBODEX now attracts more than ten thousand visitors. However, no significant business has materialized to date, except for pet robots in the toy industry. On the other hand, serious basic research on humanoid robots continues. It holds much of the future of robotics in Japan.

The most significant project has been the Humanoid Robotics Project (HRP) supported by METI. Although the project carries the title "Humanoid," its goal is not to realize human-like robots, but to develop human/robot coordinated systems for human environments. In 1998, the five-year, 5 billion yen HRP was launched. It targeted robots that can work together with human beings (Fig. 4). The National Institute of Advanced Industrial Science and Technology (AIST), the Manufacturing Science and Technology Center (MSTC), eleven university laboratories, and twelve corporations participated in the project.

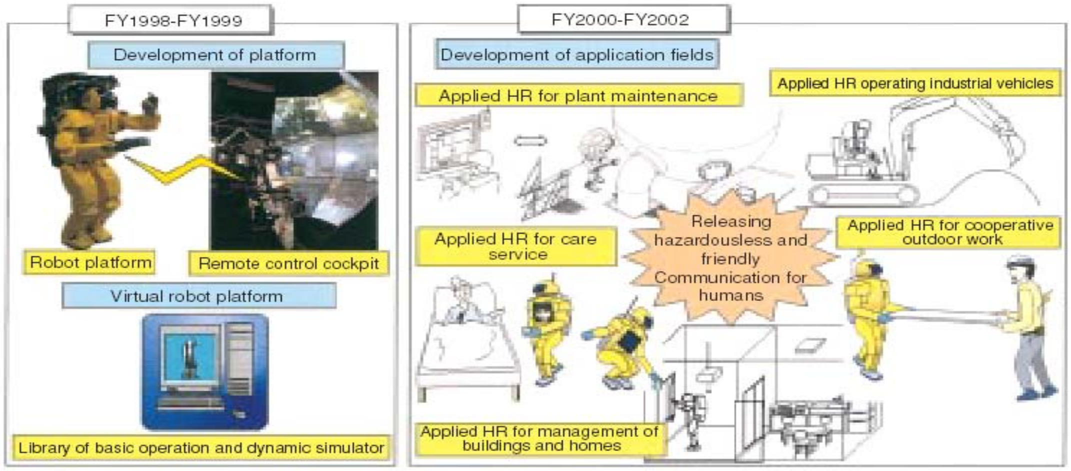

Fig. 4. Human-friendly and supportive robot systems project.

R&D carried out in the early part of the project from FY1998 to FY1999 focused on the following two themes:

(1) Development of a human friendly and supportive robot platform: Human-friendly and robot systems based on standard mechanical and electronic structures having functions that can be easily upgraded and modified, and remote-control devices were developed. Systems that have communications ability and the capability of performing basic activities and of moving among human beings were also developed.

(2) Development of a virtual human-friendly and supportive robot Platform:

A virtual human-friendly and supportive robot platform consisting of software capable of operating robot systems and simulators was developed. Simulators were also developed. In the latter part of the project, from FY 2000 to FY 2002, an application study was conducted. Modifications and additions of elemental technology were carried out through use of human-friendly and supportive robot systems and a virtual platform was developed in the early part of the project in order to put these robot systems to practical use. R&D on the following themes were carried out.

Other Robots

(1) R&D on robot systems for plant maintenance:

Robot systems and remote-control devices capable of moving and conducting inspections and maintenance in power plants were developed.

(2) R&D on robot systems for driving industrial vehicles (Fig. 5):

Robot systems to drive and operate construction machines and transporters were developed, together with mobile-type remote-control devices.

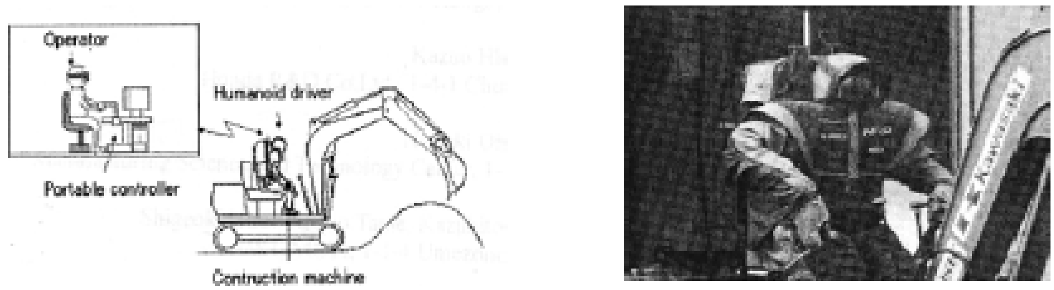

Fig. 5. Operating industrial vehicles.

(3) R&D on robots for collaborative outdoor activities (Fig. 6): Development of robot systems capable of carrying and setting up panels in wasteland areas, in collaboration with human beings, was carried out. Development of wearable remote-control devices was also conducted, so that a person can issue an order to a robot system through voice instruction.

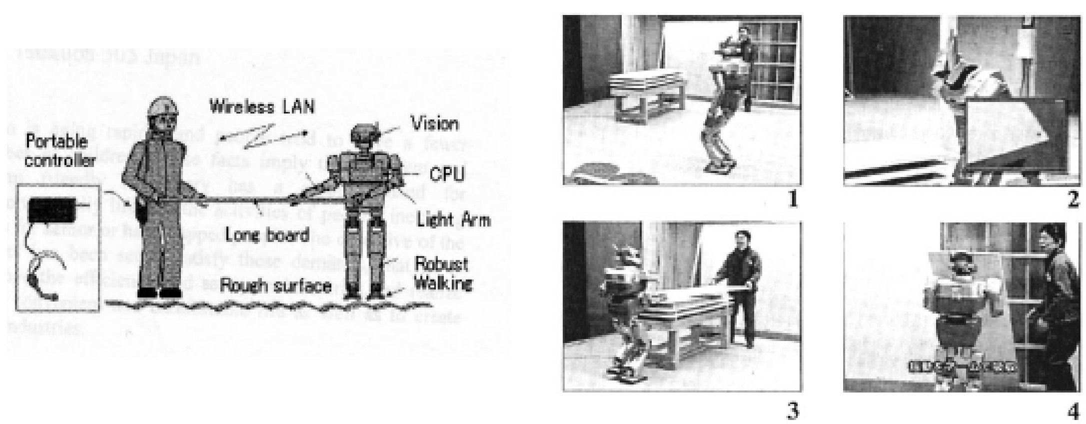

Fig. 6. Cooperative outdoor construction

(4) R&D on robot systems for personal service:

Robot systems that can help care for the aged and disabled in nursing homes and other facilities were developed, together with portable remote-control devices (Fig. 7).

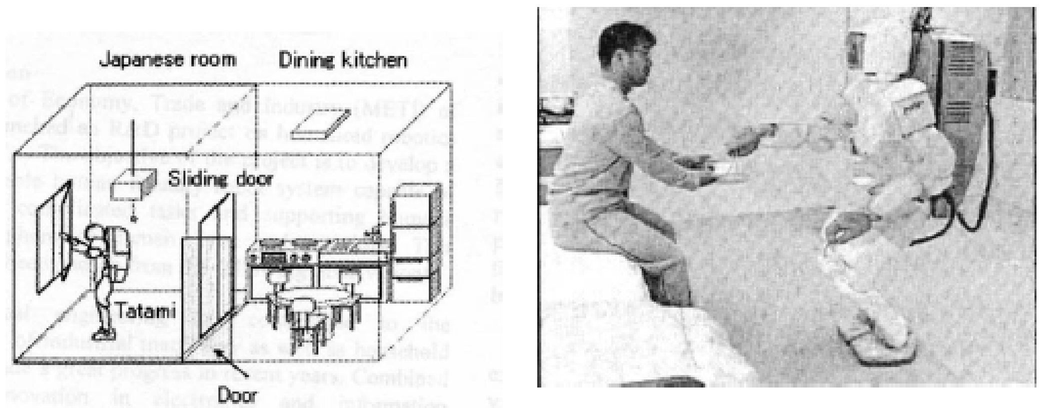

Fig. 7. Personal care.

(5) R&D on robot systems for building and home maintenance:

Robot systems capable of moving within offices and residences to obtain image information and carry out simple tasks, along with portable remote controls, were developed.

Important Centers and Projects

(1) Humanoid Research Institute, Waseda University:

Another major Japanese effort on humanoid robot research is being conducted at the Humanoid Research Institute, Waseda University. The late Prof. Ichiro Kato was a most-ardent advocate on humanoid research. He started the WABOT Project in 1970. Based on the resulting accomplishments, Waseda

University established the Humanoid Research Institute in April 2000. It was the first and the largest research institution specifically focusing on humanoid research. In addition to Prof. Hashimoto, the president of the Humanoid Research Institute, eight professors with six laboratories were at one point working on humanoid-related research.

(2) Advanced Telecommunications Research Institute International:

ATR is a research institute for communication science, the research areas of which encompass spoken language translation, adaptive communications, human information science, media information science, brain activity, and others. There are some interesting humanoid-related activities in progress. Dr. M. Kawato, Human Information Science Laboratory, believes that the human brain mechanism can be analyzed only with association with human behavior. A humanoid robot, called DB, has been developed in his lab and it, for example, can learn a folk dance just by watching a human dancing. He emphasizes that this approach will provide a powerful tool for neuroscience research to study the secrets of human brain activity.

(3) PINO:

An external organization of MEXT, the Japan Science and Technology Agency (JST) is sponsoring the Kitano Symbiotic Systems Project, which Dr. Kitano, also known as the initiator of

RoboCup competition, organizes. This project, called Open PINO Platform, is a project to develop a humanoid platform. It provides to the public all of the technical information of PINO. Everyone can use PINO as a foundation for the research and development. The first commercialized version was produced some years ago by ZMP Corporation, Tokyo.

(4) ROBOCUP:

RoboCup, initiated by Sony, is an international competition of soccer played by robots. It was established in 1995 to develop and promote robotics, artificial intelligence, and related technologies. The ultimate goal of the RoboCup is by 2050 to realize a soccer team consisting of fully autonomous humanoid robots that can win against the human world champions. According to the rules of RoboCup, robot soccer players must not be controlled by a centralized intelligence, but each should play using its own intelligence. The technology might make use of some sort of group robot-control algorithm.

(5) Pet Robots:

Although humanoid robotics is a favorite topic for the mass media to discuss, no truly profitable business has materialized. On the other hand, animal-like pet robots already enjoy an appreciable business, although still not large. Pet robots incorporate many new technologies, such as walking locomotion,

sensory perception, verbal interaction, robot-to-robot communication, coordinated work among robots, telemanipulation, emotional expression, etc., are being developed successively, which must impart an impact on future humanoid robots. JARA has organized a study group, the Entertainment Robot Forum, in which some 70 companies focus on the future robotics entertainment business. One of its on-going activities, RoboLink project, is to develop a network that links toy dolls of different makes; they communicate with each other. RoboLink is now contemplating a more-sophisticated networking scheme to allow for coordinated work by toy robots. No matter how nicely the mass media reports “Humanoid age is here!”, it has yet to come. However, motivated by the prevailing enthusiasm, a great deal of humanoid research is now going on. New accomplishments that human beings can take advantage of should result.

(6) New Actuators

In an attempt to develop innovative robots for new applications, various actuators based on new ideas are under development. They include: AC servomotors, ultrasonic motors, polymer actuators, gel actuators, functional fluid actuators, pneumatic soft actuators, electrostatic actuators, piezoelectric actuators, optical actuators, surface acoustic wave linear actuators, spherical motors, and micro-actuators.